N-08-042 Phase 1 Summary: Low-Permeability Coating for Nitrile Rubber

Objective of Phase 1 Effort

The objective was to address a reliability problem with fly-through covers for a submarine-launched missile. The basis capsule closure assembly (JCM-14051 rev H) was originally designed for the Tomahawk land attack missile (TLAM). The JCM-14051 assembly has a nylon-reinforced NBR fly-through cover, which has poor resistance to sea water. This assembly incorporates Mylar/Tin/Mylar (MTM) moisture permeation barrier that is separate from the fly-through cover. Numerous problems occurred with the MTM barrier layer, which is rather fragile. The JCM-14051 assembly was replaced for the TLAM program by a thicker assembly with an outer neoprene layer facing out to replace the MTM sea water barrier layer. This thicker assembly works well for the TLAM, but the higher break through force to pierce the redesigned fly through cover is not appropriate for a new generation submarine-launched missile. The goal is to design a sea water barrier that does not increase the force required to pierce the barrier substantially over the JCM-14051 rev H assembly design.

Summary of Results from the Phase I Effort

We studied polymer-based materials that were directly laminated to the NBR substrate. We tested elastomeric compounds, and polychlorotrifluoroethylene, PCTFE. PCTFE was a superior sea water barrier material. PCTFE can be surface modified to produce excellent adhesion to NBR; however this approach was ruled out for the fly-through cover due the poor deformability of the NBR/PCTFE bonded composite. We tested bonding to the NBR substrate using a custom-made device that we call a “puffer” that applies biaxial extension to the bonded assembly of the protective coating to the NBR. Figure 1 shows the puffer, and also that PCTFE bonded to NBR fails after the assembly is biaxially deformed 25%.

The 104 elastomeric compounds that were formulated included one NBR control compound, five high-fluorine FKM compounds, nine compounds based on ethylene/octene elastomer, with all the other compounds based on three different isobutylene copolymers (“butyl” and “bromobutyl” compounds), including one butyl rubber-based dynamic vulcanizate.

Three elastomers produced good adhesion to the NBR substrate: Lanxess Bromobutyl 2040, Dow Engage 8100, and Exxpro XP-3745. The two bromine-containing isobutylene-based copolymers (Lanxess Bromobutyl 2040 and Exxpro XP-3745) produced the lowest sea water permeability. The permeability of the candidate barrier compound was improved by various platy fillers. The best results were obtained for a graphite-reinforced bromobutyl compound, which had sea water permeability that was lower than NBR by a factor of 1000. The graphite-filled bromobutyl compound had one third of the sea water swelling of a similar N-550 carbon black reinforced bromobutyl compound, and the sea water permeability was lower by a factor of 6.5.

Potential Applications and Benefits

The discoveries of phase 1 may be applicable to other important problems. The method that was discovered to adhere PCTFE film to elastomers has potential applicability to fuel hoses, to undersea cables, and to highly corrosion resistant coatings for metal structures that are exposed to sea water for example. Ethylene/octene copolymers were found to have exceptional resistance to sea water, which may open up new applications for these polymers in insulation for underwater cables. The discovery that a particular grade of graphite produced superior permeation resistance may have broad applicability in improving permeation resistance of polymeric systems.

Figure 1: The "Puffer" used to Apply Biaxial Strain to Laminated Rubber Samples

The puffer clamps a 4.5 inch diameter laminated rubber disc between machined aluminum faces. Biaxial strain is applied by adjusting a pressure regulator behind the sample. Biaxial strain is evaluated near the apex of the domed rubber sample by measuring the separation of marks made on the surface of the rubber sample prior to inflation. At the left of the picture are two disc samples that were deliberately ruptured to verify that the samples would not pull free from the edge clamping mechanism during testing. The sample in the puffer is a laminate of chemically etched PCTFE film (.0027 inch thick) adhered to a .028 inch thick NBR sample, with PCTFE side facing out. The biaxial strain at the apex of this sample is ~25%. It is possible to see the cracks which have formed in the PCTFE film.